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Particle-size characteristics of wind eroded sediments from disturbed biotic crusts in south east Australia

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Introduction

The degrading effect of overgrazing on rangelands is well documented. Biotic crusts often stabilize the fragile soils of these grazed areas. Depending on soil characteristics and disturbance regimes, soil crust components include: mosses, lichens, algae and cyanobacteria (Belnap and Gillette, 1998). Biological crusts are susceptible to disturbance, especially in soils such as sands (Eldridge and Greene, 1994; Webb and Wilshire, 1983; Belnap and Gillette, 1997). Disturbance from compressional or shear forces acting on the vegetative components may result in the removal of biological propaguales or burial. Such disturbance of propagules will decrease recolonization rates, and lower nitrogen and carbon levels, and result in the death of the organism. Whilst the impact of grazing pressure, in particular trampling, on these protective crusts is becoming better understood, the processes by which protection is offered is less well known. We examine how disturbance of these biotic crusts by grazing animals increases the erodibility of soil surfaces to wind erosion.

Materials and Methods

Experimentation was carried out on two soil types (sand and loam) in the Mallee Region of south-western New South Wales, Australia. Both soils are in areas with low grazing pressure and are classified as Tenosols (sand) and Hypercalcic Calcarosols (loam) (Isbell, 1996). Two levels of crust disturbance were induced by simulated stock trampling with a constructed sheep foot roller (Leys and Eldridge, 1998). The disturbance levels created three surfaces of different erodibility: no disturbance, moderate and severe. Sediment fluxes were then measured using a portable field wind tunnel. A Coulter Multisizer measured particle-size characteristics of the eroded sediments.

Wind Tunnel

The New South Wales Department of Land and Water Conservation portable field wind tunnel used in this study is described by Raupach and Leys (1990). In brief, the tunnel is portable, open bottomed with a cross section of 0.9m x 1.2m and a working section length of 7.5m. The tunnel has flow conditioning and a fully developed boundary layer. Wind velocity in the tunnel was set at 6m/s at a height of 0.15m and velocity maintained for one minute. The wind velocity was then increased in increments of 1.2m/s each minute until maximum velocity of 13m/s was reached. The eroded sediment was collected at each minute interval in a modified Bagnold vertically integrating trap of width 0.005m and height of 0.5m, described by Shao et al. (1993). Sediment flux (q) was determined from the weight of soil collected by the relationship $q = m/YT$ and corrected for saltation overshoot (Leys *et al*. 1996).

Particle-sizing technique

Particle-size analysis (PSA) was performed using a Coulter Multisizer, on: surface soils and the eroded sediments from each disturbance surface. The Multisizer is an electrical sensing zone instrument (Lines, 1992) that counts and sizes particles and aggregates suspended in an electrically conductive liquid. The Multisizer provides high resolution results (256 size classes), with very good reproducibility and is one of few instruments capable of analyzing the very small quantities of material (McTainsh et al., 1997). To reduce errors arising from sample contamination with glass fibers (from the glass fiber filter papers), the exhaust discharge samples were analyzed using the method of Kiefert et al. (1992).

Results and Discussion

Sediment fluxes increased with disturbance intensity on both soils (Figure1).

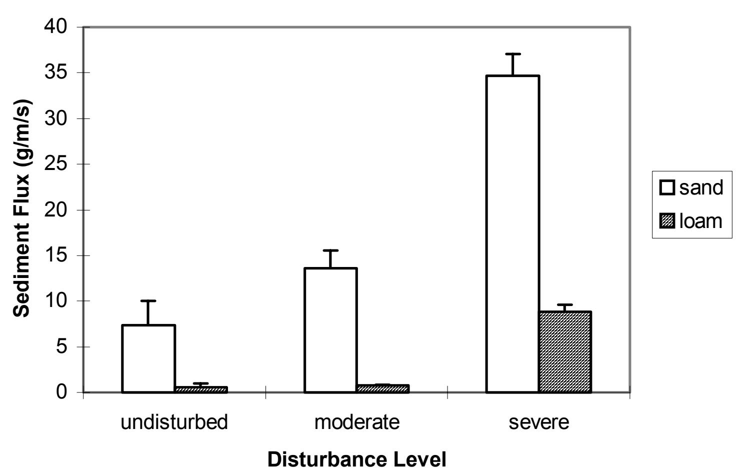

Figure 1: Sediment flux of increasing disturbance on two soils: sand and loam.

The inherent properties of each soil influence the quantity and quality of sediments removed. Particle-size distributions of the wind-eroded sediments from both soils provide evidence of wind-induced entrainment of crusted surfaces. For the undisturbed sandy soils, the biotic crust resisted saltation, offering protection to the underlying soil. However, unprotected areas between the crust cover released material with the saltating grains. This ‘puff’ of material has a particle-size similar to the parent soil. In comparison, trampling results in a coarse mode appearing with its size dependent on the level of disturbance. Moderate disturbance resulted in a mode of 420µm, while severe disturbance resulted in a 300µm mode. The severely disturbed surface produced a winnowed fine fraction, becoming finer (one 1/4ϕ class) with increased level of disturbance.

The higher clay content of the loamy soil increased the overall stability of the soil enabling colonisation of more complex morphological groups of crust taxa such as squamulose and foliose lichens. These in turn increase surface roughness and soil aggregation, enhancing soil protection from wind erosion. The large surface area of mosses and squamulose lichens acts as an efficient trap, capturing silt and larger quartz grains. This lag material was removed with the undisturbed treatment. Unlike the sandy soil, the intercrust region of the loam soil was resistant to saltation due to its greater clay content. Trampling of the loam soil resulted in two sediment populations within the eroded sediments, a winnowed population sourced from the freshly exposed soil and a coarser population containing organic matter and biotic crust pieces.

Conclusions

Biological crusts offer protection to soil against wind erosion, but stock trampling reduces this protection. Sediment fluxes on two soil types increased exponentially with crust disturbance and the particle-size characteristics of the eroded sediments are dependent upon soil type and degree of stock trampling.

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